Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

Reserve
aS21
.A7545
cop1

A MOBILE RECORDING AND MONITORING WEATHER TOWER

ARS W-41
December 1976

FEB 4 1977

WESTERN REGION

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

ABSTRACT

A mobile recording weather tower has been developed for measuring temperatures and horizontal windspeeds at five elevations. Humidity is determined from wet- and dry-bulb temperature readings. Wind direction is sensed at the top of the tower. A stepping switch with an adjustable timer selects each measurement to be plotted on a single pen recorder. The signals are sensed as voltages to minimize line loss and switch losses. The signal circuits and recorder amplifier are designed to provide a direct plot on the chart, which is scaled 0 to 120. Temperatures are plotted from 40° to 120° F, whereas windspeed and direction signals are adjusted to fit the full chart scale. The tower is mounted on a two-wheel trailer for mobility. The electrical components are battery driven and the tower can operate unattended up to 24 hours. Accuracy of record for temperature is ±2° F and for windspeed is ±0.5 mi/h.

KEYWORDS: Mobile weather tower, monitoring weather, temperature, windspeed, humidity, macro climatic measurement, atmospheric stability measurement.

ACKNOWLEDGMENTS

The authors acknowledge the technical assistance and advice of the personnel of the Instrument Laboratory, Bonneville Power Administration, Ross Substation, Vancouver, Wash.; K. H. Norris, Director, Instrumentation Laboratory, Market Quality Research Division, Agricultural Research Service (ARS), U.S. Department of Agriculture (USDA), Beltsville, Md.; G. Pleasant, Traffic Department, City of Yakima, Wash.; and the National Weather Service, National Oceanic and Atmospheric Administration, Yakima Airport, Wash., for assistance in checking our recorded values with their weather record. We also acknowledge L. E. Stevens, engineering technician, ARS, USDA, Yakima, Wash., and W. C. Wilson, machinist (retired), ARS, USDA, Forest Grove, Oreg., who were involved in the original planning and did much of the original construction.

CONTENTS

	Page
Methods and materials	1
Specifications	1
Weather tower components	1
Sensing element arrays	2
Switch and timer unit	6
Amplifier	9
Recorder	10
Temperature readout	10
Power supplies	11
Summary	12
Suggested sources of supplies	12
Literature cited	13

Trade names and the names of commercial companies are used in this publication solely to provide specific information. Mention of a trade name or manufacturer does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture nor an endorsement by the Department over other products not mentioned.

A MOBILE RECORDING AND MONITORING WEATHER TOWER

By P. A. Boving and R. G. Winterfeld[1]

METHODS AND MATERIALS

Specifications

The following specifications for a weather tower, comparatively different from that of Haynes (*3*)[2], were drawn up to meet our particular weather data needs in studies of aircraft spray applications:

- The tower should be capable of being moved and erected by one person.
- Once started, the tower should operate unattended.
- Electric power should be provided by batteries for operation at remote locations.
- All data should be plotted on one strip chart to facilitate transportation.
- Sensing element arrays and cables should be standardized to permit interchangeability.
- The heights of the sensing element arrays above ground should be 32, 16, 8, 4, and 2 ft (or top of crop height).
- Since 15 or more measurements will be recorded, a switching circuit, controlled by an adjustable timer, should be used.
- Thermistors should be used for the temperature and windspeed sensors.
- They should be wired into bridge circuits, and the outputs fed via the switching circuit to a linear voltage amplifier that drives the recorder.

Weather Tower Components

The components that make up this measurement system are as follows: (1) Sensing element arrays, for sensing wet- and dry-bulb temperatures and windspeeds; (2) temperature readout, a commercial unit that includes a bridge circuit for detecting the temperatures sensed in the arrays, a meter to indicate the temperatures being sensed, and recorder output terminals; (3) switch and timer, a fabricated unit that contains the stepping switch and timer and acts as a junction box for the sensing element arrays, ancillary circuits, and the amplifier to the recorder; (4) amplifier and recorder in which the amplifier input matches the impedance of the signal outputs, and the output drives the pen movement; and (5) power supplies, various batteries needed to power the different circuits.

---

[1]Agricultural engineer and aircraft pilot, respectively, Yakima Agricultural Research Laboratory, Agricultural Research Service, Yakima, Wash.

[2]Italic numbers in parentheses refer to Literature Cited, p. 13.

Each of these components is described in detail in this publication. The wind-direction system was purchased already assembled and is described in the "Switch and Timer Unit" section.

Because the tower itself and the trailer (fig. 1) were made up from avail-

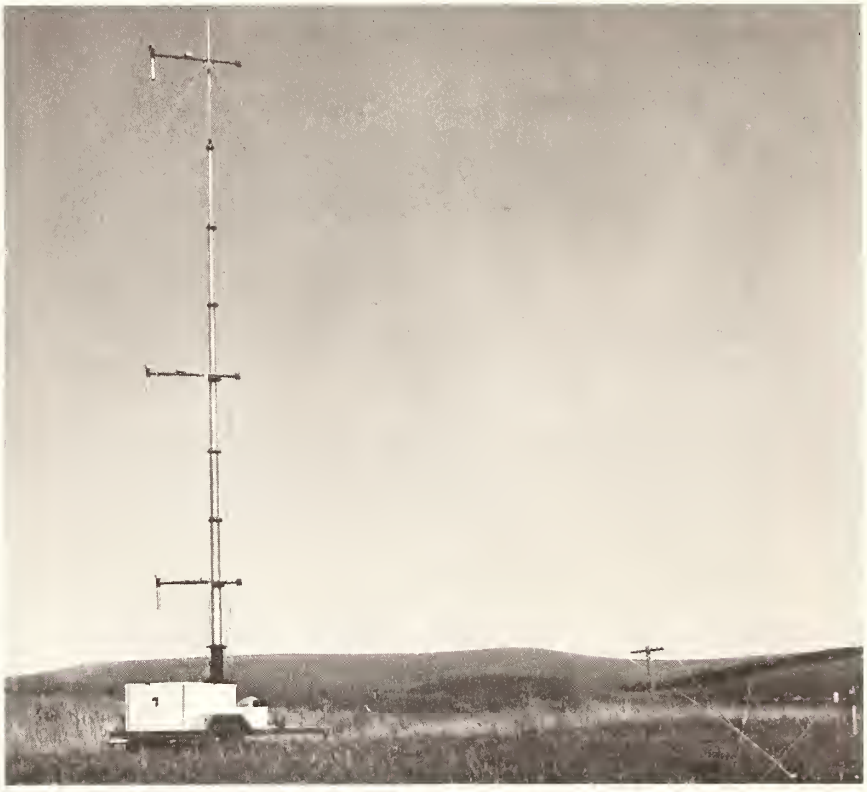


Figure 1.--Weather tower erected in a field near Palouse, Wash.

able components, descriptions of them would be of little value. A wooden cabin was built on the trailer to provide security and weather protection for the recorder, switching circuits, and batteries. The cabin was ventilated and painted white to reduce solar heating.

Sensing Element Arrays

The five sensing element arrays used to detect the wet- and dry-bulb temperatures and the windspeeds are based on Lourence and Goddard's (5) design for an aspirated wet- and dry-bulb temperature probe (fig. 2). Each array has an arm 44 inches long made from 1-inch heavy-wall plastic pipe. The arms are clamped to brackets on the tower or the stand to hold the arrays at their desired heights. Each arm has a junction box clamped to it for the cable to the switch and timer unit.

The arm (as shown in fig. 3) is an air duct as well as the support for the aspirating fan at one end. The other end of the arm is fitted with a plastic tee having the open ends facing up and down. The upper opening is used as a socket for mounting the windspeed sensor and is sealed by the mounting and a plastic disk. The lower opening of the tee leads to the temperature sensors, which are held in a shielded chamber--a length of plastic pipe covered with two

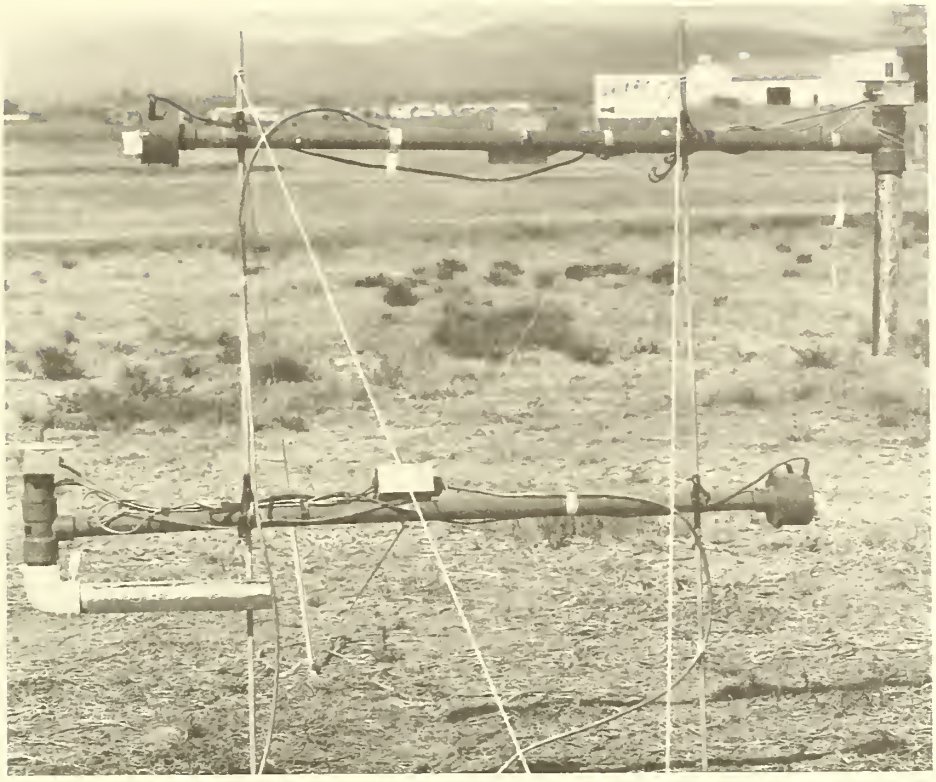


Figure 2.--Stand holding 4-ft and 2-ft arrays with lower array modified to gather data at crop height.

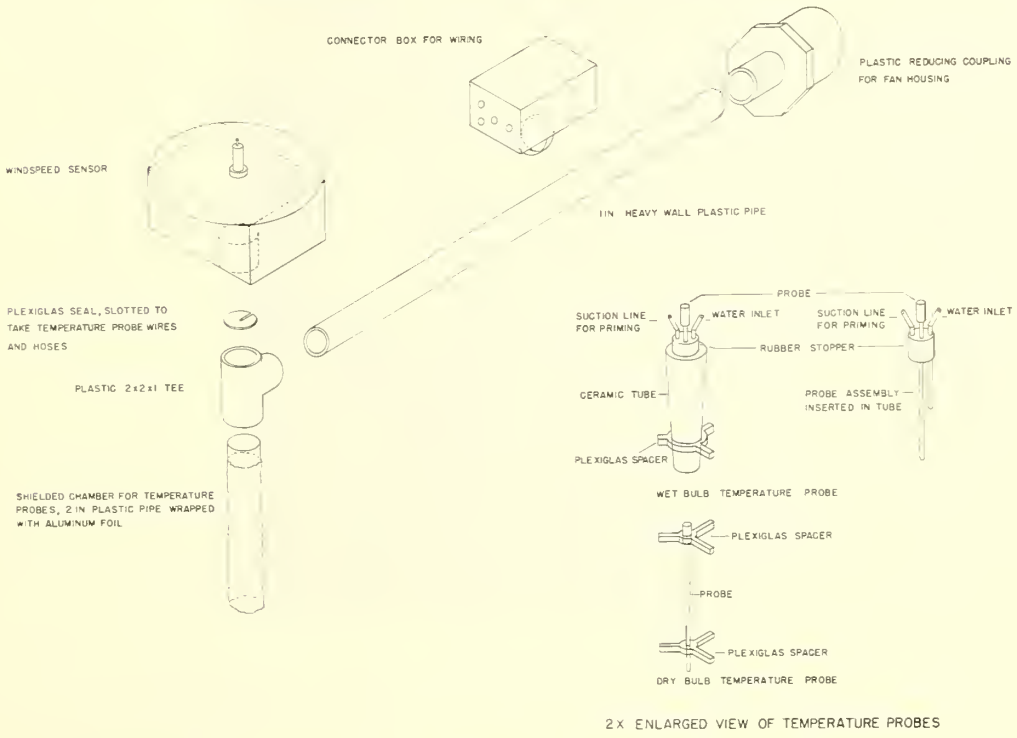


Figure 3.--Sketch of a sensing element array, showing how the unit is assembled.

layers of aluminum foil. The aspirating fan draws air through the shielded chamber past the temperature sensors. The chamber is mounted vertically to avoid wind effects on the aspiration rate as well as to provide solar shielding to the probes.

Aspirating Fan

A 6-V, permanent magnet, direct current motor drives a 3-inch diameter, six-bladed fan, which is centered in a plastic reducing coupler for a housing. The wiring of the five aspirating fans is as follows: Three of these motors are connected in series to the 12-V battery; the other two motors are connected in series with a 20-W variable resistor to the same battery. The resistor is adjusted to produce a 4-V drop when the motors are at operating speed. At 4 V, these fans provide an aspirating velocity of 220 ft/min.

Windspeed Sensor

The method used in this sensor is to pass a sufficient current through a thermistor to raise the temperature of the bead well above ambient conditions. The thermistor assumes a steady resistance as long as the cooling rate matches the energy input. Air movement increases the cooling rate, which lowers the bead temperature, and thereby increases the resistance. This sensor (fig. 4) consists of a matched pair of thermistors wired in a bridge circuit. Each leg

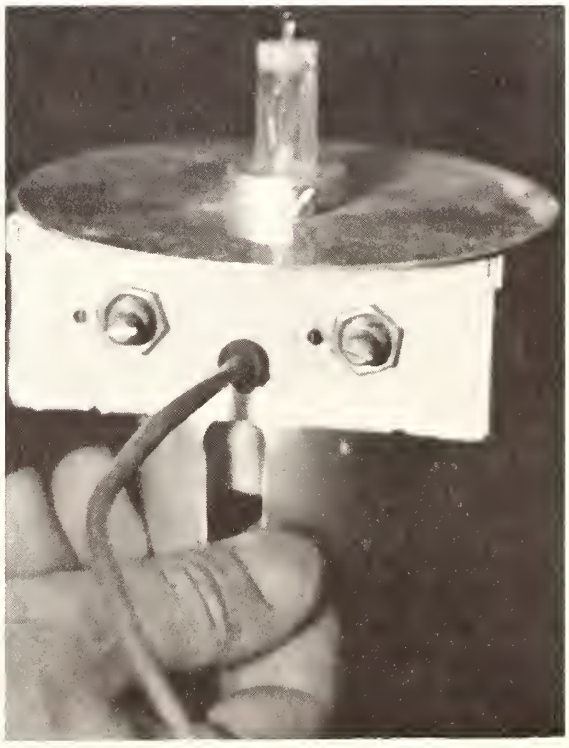


Figure 4.--Windspeed sensor showing adjustment controls and slot in plug for temperature sensor cables.

of the bridge passes sufficient current to raise the temperature of the thermistor beads to about 300° F. A clear plastic tube is sealed at the top to support

one thermistor exposed to air movement, while the second thermistor is shielded inside the tube (Fenwal Electronics, Inc., (2); Martino and McNall, (7); Pollack, (8); and Witz et al.[3]). Air movement cools the exposed thermistor to unbalance the bridge and generate a signal. The plastic tube is used to reduce heat conduction from the metal box on which the sensor is mounted. A 4-1/2-inch diameter plate is used as a baffle to eliminate vertical airflow and eddies due to the box (fig. 4). The metal box contains the bridge circuit, voltage regulator, and trimming resistors for conditioning the signal (fig. 5).

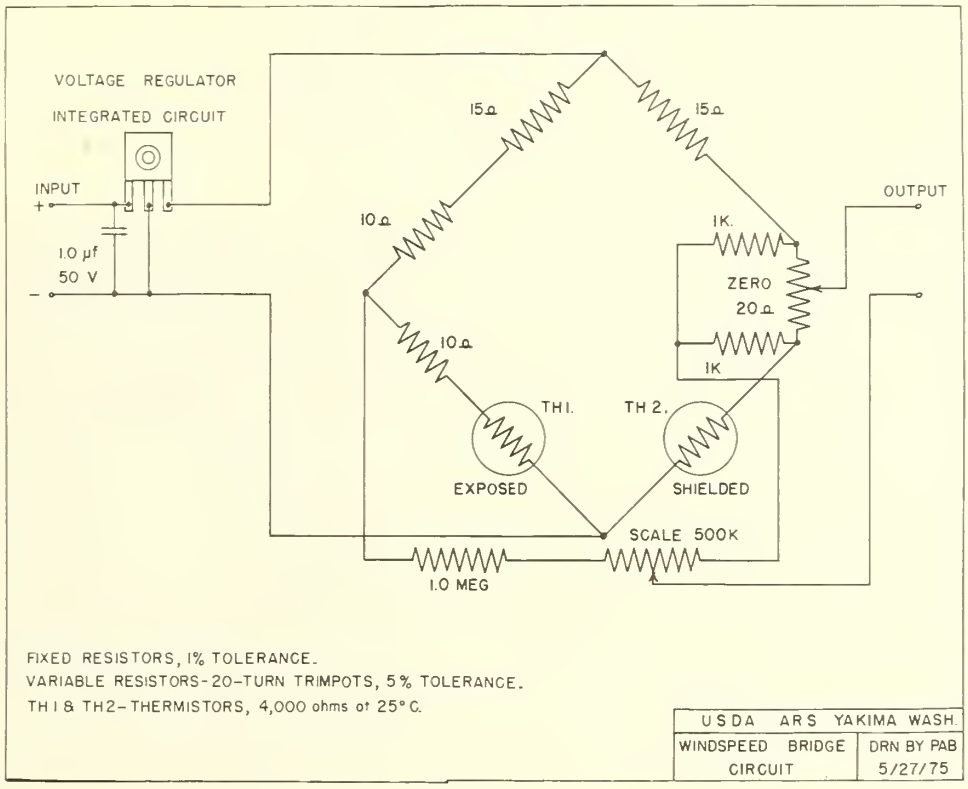


Figure 5.--Wiring diagram for windspeed sensor.

The sensors operate continuously on the 12-V power supply, and the output signals are fed to the stepping switch.

Temperature Sensors

The method used in this sensor is to pass a small current through the thermistor so that the bead is not heated. The bead then assumes ambient temperature and develops the appropriate resistance for that temperature. By measuring the resistance in a bridge network, the temperature can be detected. The temperature sensors (Yellow Springs Instrument Co., No. 406 Probes) shown in figures 3 and 6 are centered one above the other in the shielded chamber using Plexiglas

---

[3]Witz, R. L., Butchbaker, A. F., and Gunnarson, H. J. The design and testing of a thermistor transducer to measure very low air velocity. Paper No. 66-834 presented at the 1966 Winter Meeting, Amer. Soc. Agr. Engin., Chicago, IL, 10 pp. 1966.

spacers. The lower probe is bare to sense the dry-bulb temperature. The upper probe is sealed in an unglazed ceramic tube to sense the wet-bulb temperature. The space between the ceramic tube and the probe is filled with water and is connected to a supply bottle. The ceramic tube avoids the problems of flooding and drying associated with fabric wicks, and the evaporation from the surface of the ceramic develops sufficient suction to maintain the water level from the supply bottle.

Switch and Timer Unit

The following components are mounted in a metal chassis: Stepping switch, timer circuit, power supply for wind direction signal, and control switches (fig. 6). The front panel contains control switches, sockets for the cables that lead to the sensing element arrays, temperature readout, wind direction vane, and the output to the amplifier.

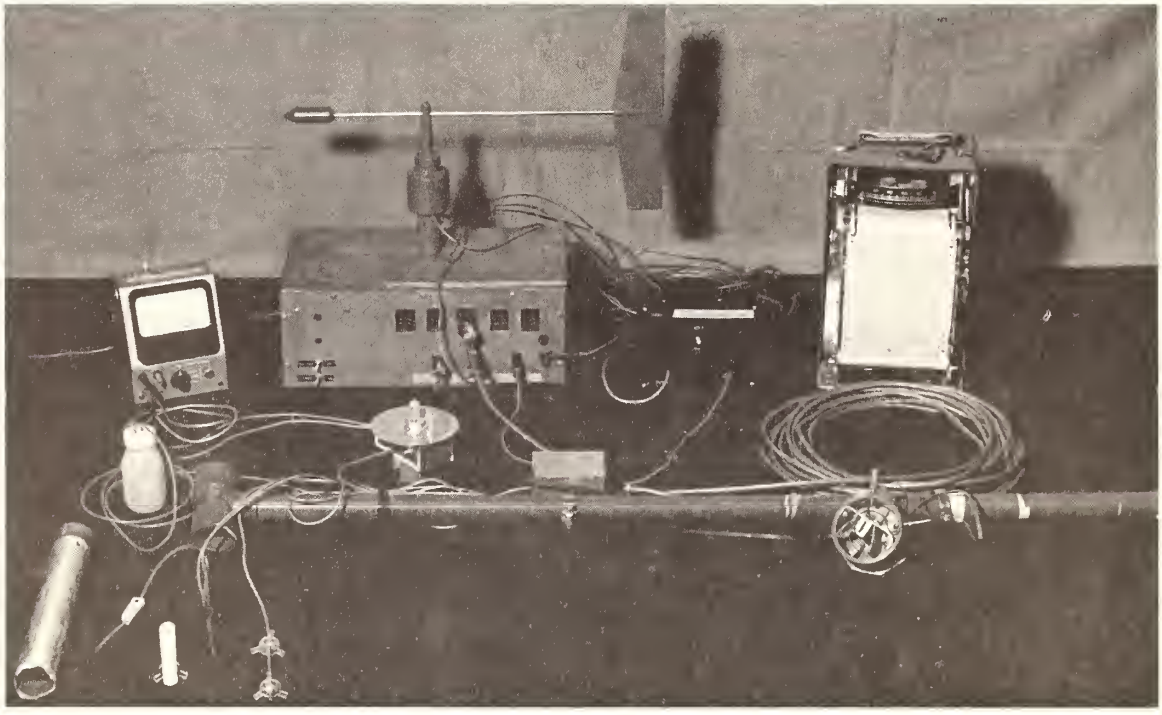


Figure 6.--Components of weather tower. Background, left to right: Temperature readout, switch and timer unit with wind vane on top, amplifier, and recorder. Foreground: Array taken apart to show components.

The stepping switch (fig. 7) is a rotary contact switch similar to that used in automatic telephone switchboards and has five levels of 23 contacts. The solenoid winding of the switch operates on 12 V d.c., and the contacts are gold-plated to reduce their resistance. Three levels of the stepping switch are used to select the signal to be recorded, and the fourth and fifth are used in homing the switch (that is, returning the wiper arm to the first signal position when the scan cycle is completed). The three levels are used simultaneously at each of the 16 positions to select the desired signal and link up the appropriate circuit. The first level selects the desired temperature probe, connecting it to the temperature bridge and indicating meter; second and third levels connect the

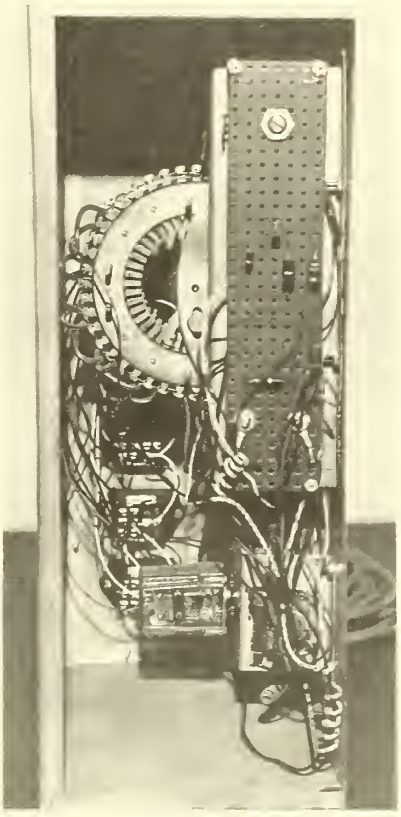


Figure 7.--Rear view of stepping switch and timer unit.

recorder amplifier to the output signals from either the temperature bridge, the windspeed bridges, or the wind direction circuit. Two levels are used to ensure complete isolation of the signal being recorded. The fourth level, used in the homing phase, provides a chart-marking signal, and the fifth level is part of the homing circuit. The wiring of the stepping switch is detailed in table 1.

The timer circuit provides pulses for driving the stepping switch solenoid through an isolating relay (James, *4*). The circuit (fig. 8) is based on Witz and Stegman's[4] timer modified by adding a second silicon-controlled rectifier (SCR) to shut off the first one (Marston, *6*). The timer employs a unijunction transistor as a relaxation oscillator to generate pulses for triggering the SCR's. The interval between the pulses can be varied from 5 seconds to 1 min.

Power for the wind direction signal is taken from the storage battery. A zener diode provides a constant 4.5 V for the circuit. The wind vane positions a wiper on a precision potentiometer, so that the wind direction signal is a portion of the voltage across the potentiomenter. The signal is then reduced by a resistance network to match the amplifier input.

Power from the storage battery (12 V) is controlled by a master switch. This switch governs the aspirating fans, the windspeed sensors, the wind direction circuit, and the timer and stepping switch. A second switch controls the

---

[4]Witz, R. L., and Stegman, E. C. Solid state timing circuit for stepping switch. Paper No. 70-538 presented at the 1970 Annual Meeting, Amer. Soc. Agr. Engin., Minneapolis, MN, 4 pp. 1970.

TABLE 1.--*Wiring for stepping switch*

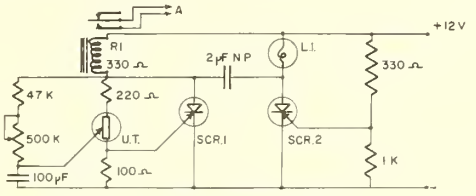
Wiper arm	Contact numbers and stepping switch levels				
	1 To temperature P.C.* (+)	2 To input amplifier (+)	3 To input amplifier (-)	4 To input amplifier (+)	5 To timer circuit**
1	Wet $bulb_1$***	Temperature readout output			
2	Dry $bulb_1$	--do--			
3		Wind $bridge_1$ output			
4	Wet $bulb_2$	Temperature readout output			
5	Dry $bulb_2$	--do--			
6		Wind $bridge_2$ output			
7	Wet $bulb_3$	Temperature readout output			
8	Dry $bulb_3$	--do--			
9		Wind $bridge_3$ output			
10	Wet $bulb_4$	Temperature readout output			
11	Dry $bulb_4$	--do--			
12		Wind $bridge_4$ output			
13	Wet $bulb_5$	Temperature readout output			
14	Dry $bulb_5$	--do--			
15		Wind $bridge_5$ output			
16		Wind direction output			
17-23				Contacts wired to amplifier (-) for signal marker	Contacts shorted to ground for "home" signal

*P.C. (+) Probe connection on YSF Model 42SF Tele-thermometer. P.C. (-) tied to probe cable shields.

**See fig. 8.

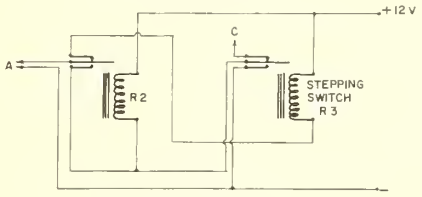
***Subscripts 1 to 5 are sensing element array numbers.

timer and stepping switch to permit the normal monitoring cycle, indexing the cycle, or recording one channel continuously.



TIMER CIRCUIT

UT	UNIJUNCTION TRANSISTOR 1R 2160-C
SCR	SILICON CONTROLLED RECTIFIERS SCR-01-C
N P	NON-POLARIZED CONDENSER
L.I.	INDICATOR LIGHT 12 V 500 MA
A	LEADS TO STEPPING SWITCH RELAY



STEPPING SWITCH CIRCUIT

R 1	SENSITIVE RELAY 12 V 330 Ω
R 2	RELAY, HEAVY DUTY POINTS 12 V. 120 Ω
R 3	STEPPING SWITCH, HEAVY CURRENT 10 Ω
A	LEADS TO TIMER RELAY R1.
C	CONTACT FOR 'HOMING' STEP SW

TIMER & STEPPING SWITCH CIRCUITS

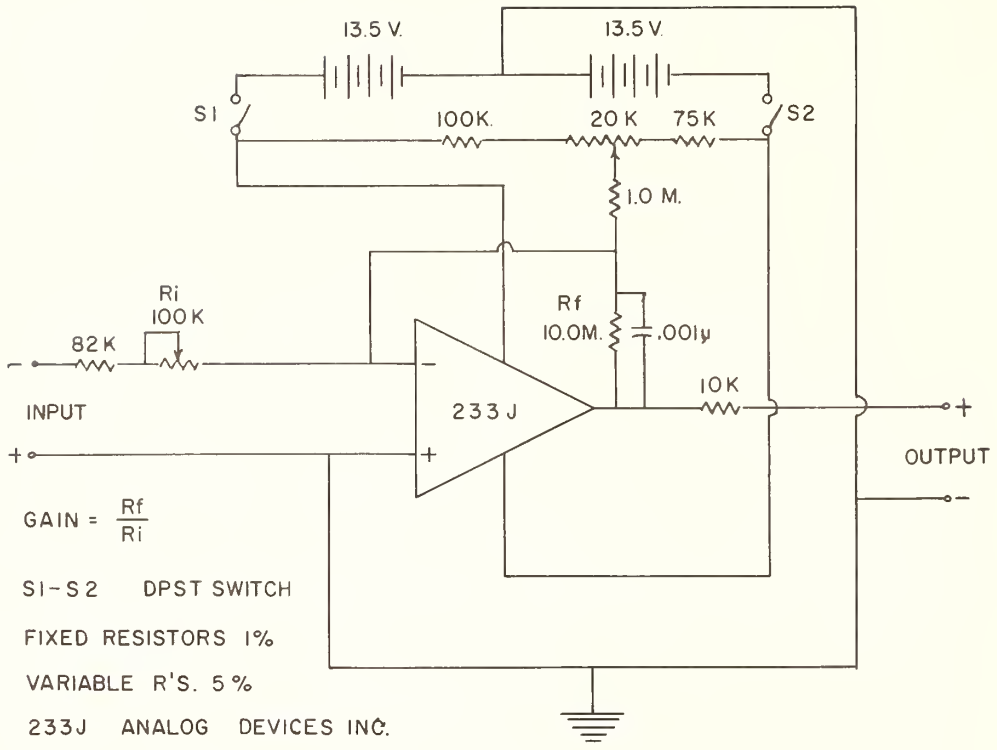
Figure 8.--Wiring diagrams for timer and stepping switch circuits.

Amplifier

The recorder pen movement draws more current than the signal bridges can deliver so a linear blocking amplifier is used to isolate them. In correspondence regarding amplifiers, Norris (personal commun., 1972) suggested using a solid-state amplifier (Analog Devices, Inc., Model 233J). This is a chopper-stabilized inverting amplifier, powered by a center-tapped 28-V battery. The components were assembled as a self-contained unit, and the circuit (fig. 9) is sufficiently stable that after shop-calibrating the trimmer resistors, the only control needed is the battery switch on the box lid.

An inverting amplifier is needed because the output of the temperature bridge unit is inverted. At the same time, an inverting amplifier is more stable than a noninverting amplifier and can operate with one input grounded to the circuit ground (Demerow, *1*), although the gain per stage is less. Since low gain was needed in this application, the input impedance of the amplifier could be high enough to avoid loading each of the bridge circuits.

The amplifier is calibrated by using a substitute resistance connected to the temperature readout and adjusting the "zero" and "scale" trimming resistors to obtain the best match between the dial indication on the readout and the strip chart. Since all the other sensors have their own zero and scale controls, they are adjusted to match the setting of the amplifier, and all calibrations are made to the chart record rather than the voltages that could be measured.



WEATHER TOWER RECORDER AMPLIFIER

Figure 9.--Amplifier circuit.

Recorder

The Esterline-Angus recorder is a conventional single-pen strip-chart unit, using a left-hand zero position. The pen movement draws 1 milliamp at 120 millivolts for a full-scale deflection. The chart is driven by clockwork at a rate of 12 in/h for maximum clarity of record while using a minimum of paper. The charts are 6 inches wide and are marked 0 to 120. This permits direct indication of Fahrenheit temperature, a windspeed scale of 0 to 12 (or factors thereof), and a wind direction of 0 to 360° azimuth by multiplying the chart reading by three. A sample of the chart is shown in figure 10. Date, time, and location are written on the chart by the operator at each change of the record so the clockwork movement does not need exact regulation. Field use has shown that timing the starting and stopping of the record is easiest at the homing phase of the stepping switch. The switch makes a distinct sound as well as a mark on the chart.

Temperature Readout

A Yellow Springs Instrument Co. Model 42SF Tele-thermometer and Model 406 probes are used for temperature sensing and indication. The Tele-thermometer (illustrated in fig. 6) has a self-contained power supply and output terminals for a recorder. The wiring of the "MID" range (normally reading 70° to 180° F) was altered to read 40° to 150°. This circuit was checked with controlled-temperature baths and found satisfactory for the range of 40° to 120°, sufficient for temperature and humidity measurement during the growing season. The voltage

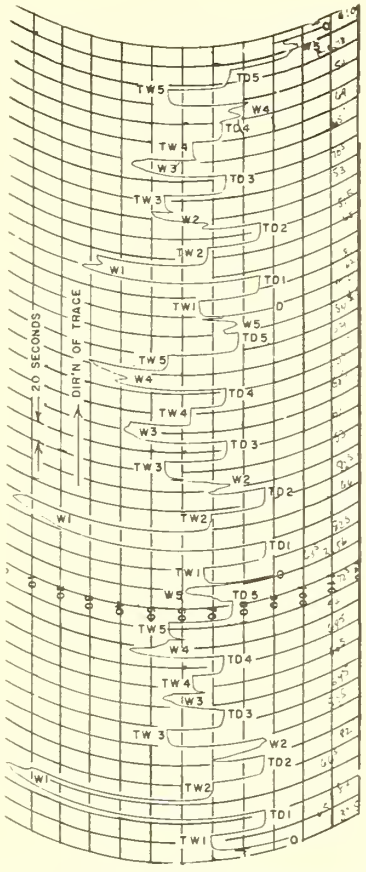


Figure 10.--Portion of a record showing typical weather trace (wind direction is not shown).

output of the recorder, however, is inverted (that is, 150° = 0 mV, and 40° = -120 mV). This necessitated the inverting amplifier for the recorder, as well as the inversion of the signal outputs from the other sensor circuits.

Power Supplies

The various circuits and power supplies installed in the weather tower are listed below. Since voltage requirements are different for each type of sensor, separate supplies are used, and this separation enhances signal isolation.

- *Amplifier for recorder* uses 28-V center-tapped power source (4 Eveready E135 Instrument batteries, or equivalent).
- *Temperature bridge and readout* use 14-V center-tapped power source (2 Eveready E135 batteries).
- *Windspeed bridges* use 12-V storage battery.
- *Wind direction signal* uses 12-V storage battery.
- *Aspirating fans* are wired series-parallel to 12-V storage battery to provide 4 V for each fan motor.
- *Stepping switch and timer* use 12-V storage battery.
- *Chart drive* uses hand-wound chronometer drive.

SUMMARY

The mobile recording and monitoring weather tower provides reasonable field data for 72 hours to 10 days, with servicing every 12 h. By recording 16 signals every 15 min, this tower logs about 1,400 readings every 24 h. Transcription, tabulation, and plotting are manual. The cost for the sensing element arrays, cables, and the electronics is about $2,700 (excluding the trailer and tower).

This tower has been used for 4 years to monitor weather conditions at field plots before, during, and after making applications in tests of aerially applied insecticides. The tower was set up at the edge of the plots, out of the line of flight of the aircraft, while permitting the 4-ft and 2-ft sensing arrays to measure conditions in the crop. The tower has also been used in an orchard to record ambient conditions during the fall migration of the green peach aphid, *Myzus persicae* (Sulzer). In this test, sticky board traps were raised to the array heights. The traps were changed regularly so that the times of flight (by trap count) could be determined and correlated with weather conditions. The tower has also been used to monitor windspeed and weather data during evening hours in studies on the effect of pheromones on the codling moth, *Laspeyresia pomonella* (L.).

SUGGESTED SOURCES OF SUPPLIES

The following is a list of manufacturers or suppliers whose products were used or from who literature was collected during the construction of the tower. The list has been developed as a guide only.

1. Trailers (2-wheel chassis only):
   a. Montgomery Ward and Co.
   b. Sears Roebuck and Co.
2. Towers:
   a. Genie Hoist Co., 2924 Western Avenue, Seattle, WA 98121
   b. Rohm Manufacturing Co., 6718 West Plant Road, P.O. Box 2000, Peoria, IL 61601
   c. Tri-Ex Tower Corp., 7182 Rasmussen Avenue, Visalia, CA 93277
3. Recorders:
   a. Esterline-Angus Instrument Co., P.O. Box 24,000, Indianapolis, IN 46224
   b. Rustrak Instrument Div., Gulton Industries, Inc., Municipal Airport, Manchester, NH 03103
4. Amplifiers, blocking (inverting, chopper-stabilized):
   a. Analog Devices, Inc., P.O. Box 280, Norwood, MA 02062
   b. Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85734
5. Stepping switches:
   Automatic Electric, GTE, 400 North Wolf Road, Northlake, IL 60614
6. Thermistors:
   a. Temperature units
   Yellow Springs Instrument Co., Yellow Springs, OH 45387
   b. Windspeed units
   Fenwal Electronics Co., Framingham, MA 01701
7. Aspirating fans:
   a. Globe Division of TRW, Inc., 2275 Stanley Avenue, Dayton, OH 45404

b. Rotron "Nugget" Fan, Rotron Corp., Inc., Hasbrouck Lane, Woodstock, NY 12498

c. Brailsford & Co., Inc., Milton Road, Rye, NY 10580

8. Wind vane:
   Weather Measure Corp., P.O. Box 41257, Sacramento, CA 95841

9. Miscellaneous:
   The tower wiring was assembled with Cinch-Jones connectors. Other connectors can be used for a more weather-proof joint. Miscellaneous cable, resistors, condensers, and transistors were obtained from local electronic parts dealers.

LITERATURE CITED

(1) Demerow, R.
1968. Evolution from operational amplifier to data amplifier. Analog Devices, Inc., 221 Fifth St., Cambridge, MA 02142. Paper E010-40, 8 pp., illus.

(2) Fenwal Electronics, Inc.
1962. Thermistor manual. Fenwal Electronics, Inc., 63 Fountain St., Framingham, MA 01701. Publication EMC-5, 20 pp., illus.

(3) Haynes, B. C., Jr.
1968. Meterological data logger for use in study of agricultural spray deposition. U.S. Dept. Agr., Agr. Res. Serv. ARS 42-128, 27 pp., illus.

(4) James, V. E.
1967. How to use rotary stepping switches. Ed. 2, 154 pp., illus. Automatic Electric Co., Northlake, IL.

(5) Lourence, F. J., and Goddard, W. B.
1967. Instrumentation development and calibration. Ch. II, Ann. Rept., Energy, Momentum and Mass Transfers Above Vegetative Surfaces. U.S. Army Electronics Command, Atmos. Sci. Lab., Res. Div., Fort Huachuca, AZ, and Univ. Calif., Davis. 44 pp., illus.

(6) Marston, R. M.
1969. 20 SCR circuits you can make. Radio Electronics. Part I: 49-51. Part II: 55-58 and 86-87, illus.

(7) Martino, F. S., and McNall, P. E., Jr.
1971. A thermistor anemometer for the measurement of very low air velocities. Rev. of Sci. Instruments 42(5): 606-609.

(8) Pollack, H.
1957. No moving parts! An electronic anemometer. Pop. Electronics (Feb.): 51-54, illus.

☆GPO 790-121-1977

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
WESTERN REGION
2850 TELEGRAPH AVENUE
BERKELEY, CALIFORNIA 94705

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U. S. DEPARTMENT OF
AGRICULTURE
AGR 101

1465 UNALPS A422 03054 0001
USDA NATIONAL AGRICULTURAL L-
IBRARY
PROCUREMENT SECTION/CURRENT
BELTSVILLE MD 20012